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A SIMULATION OF THE BONUS INCENTIVE RECRUITER MODEL (BIRM)

by

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The first part of this thesis describes a method for developing the bonus table that ties the recruiter's forecast to his actual production. The recruiter's decision problem is analyzed through an influence diagram and decision tree. The recruiter's decision is also modeled using utility theory, which provides a basis for the simulation. The bonus table, together with the recruiter's utility and cost functions, are used to estimate the amount of time and cost it takes the recruiters (in aggregate) to meet the Army's recruiting mission.

The data from the simulation was used to estimate the effects of the utility, cost and production functions. The simulation found that USAREC should meet the Army's manpower goals with the BIRM and the cost should be less than hiring additional recruiters.

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A SIMULATION OF THE BONUS INCENTIVE RECRUITER MODEL (BIRM)

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THESIS DISCLAIMER

Additionally, the reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made within the time available to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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EXECUTIVE SUMMARY

The United States Army Recruiting Command (USAREC) must increase their efficiency as they enter the 21st century. The current quota-based incentive system may not be the most efficient/effective way to motivate recruiters to produce at their highest levels.

The Bonus Incentive Recruiter Model (BIRM) is an incentive structure that allows the recruiters to provide input on how much their local area can produce. The recruiters provide this information to USAREC by forecasting how much they can produce for each month. The recruiter's incentive to forecast accurately and at the highest possible level is a bonus paid to them for their production.

A bonus table developed by USAREC shows the recruiters what payment they would receive if they forecast and produce at different levels. The bonus table is a critical element of the BIRM, because if the bonus payments are too low, then the recruiters will not be motivated to produce, and if the bonus payments are too high, then USAREC will pay more than is necessary for the recruits.

An algorithm has been developed to calculate the bonus table. It ties the recruiter's forecast and production into the bonus payment, so that if the production is greater or smaller than the forecast, then the recruiter does not earn the maximum amount that he could have. Several factors that should be considered when developing the bonus table are discussed, such as the starting level of the payments and the minimum number of recruits that must be achieved in order to enter the bonus table.

The primary key to the BIRM is to understand what influences a recruiter's decision to forecast a certain production level. Two different methods were used to model this recruiter's decision problem. The first method used decision theory

constructs. This process revealed that if a recruiter used expected values to make his decision, then he should forecast what the market will allow him to produce.

The utility based model dealt with the utility the recruiters derived from the bonus payment. USAREC controls the levels of the bonus payments, and an assumption was made that the bonus payment influences the recruiter's producuction. A well-known logarithmic utility function was used to model the recruiter's utility function for money, which modeled the recruiter's utility as risk averse. A cost function that modeled the cost to the recruiter for recruiting p recruits was generated. This cost was the sacrifice the recruiter felt he had to pay to achieve p recruits.

Two measures of effectiveness (MOE) were established for this analysis. The first MOE was the time to completion (TTC) of the recruiting objectives. Regardless of what incentive system the recruiting command used, the recruiting command had to meet its required number of recruits for enlistment. This MOE measures the expected time for the recruiters to finish the recruiting year. Under both the quota and BIRM systems, the recruiters would complete their recruiting mission within the recruiting year, but the majority of the recruits under the BIRM would be recruited early in the recruiting year.

The second MOE measured the cost of the different incentive systems. An assumption was made that the only relevant cost under the quota system was the supplementary pay given to recruiters for being active Army recruiters. The supplementary pay ranges between \$165 and \$275 per recruiter per month. In the BIRM, the simulation totaled the bonus payments awarded to recruiters until they met their recruiting goal.

When the costs of the quota based system were compared with simulation generated BIRM costs, the costs under the BIRM were significantly lower than the costs under the quota system. Even the worst case cost of the BIRM was better than the expected cost under the quota system.

Sensitivity analysis was conducted on the factors that influence the BIRM. In the simulation, the recruiter's production was modeled as normally distributed with respect to the forecast and then beta distributed with respect to the forecast. The analysis revealed that the production distribution does not significantly affect the time to completion and cost of the BIRM. Three of the four parameters from the utility and cost functions were found to be significant to the TTC variable and cost variable. Future empirical work should attempt to determine the exact nature of these distributions, especially the recruiter's cost function, since both parameters of the cost function, along with some of its interactions, were significant.

Overall, the BIRM should outperform the quota-based system. Under the quota-based system, each recruiter would have to produce 1.5 recruits per month, or six recruits in a four month period. Under the BIRM, the recruiters would have to produce 1.75 recruits per month, or seven recruits in a four month period. Although the recruiters would have to produce only one more recruit over the four months, they would receive a bonus for the production of three of the seven recruits. The cost of paying this recruiter the bonus was found to be less than hiring more recruiters.

USAREC should initiate a pilot study to test the BIRM with actual recruiters at a battalion. A battalion is recommended for the smallest test group because a battalion can encompass diverse recruiting environments. In this manner, data could be collected on the diverse situations in which recruiters work.

I. INTRODUCTION

A. BACKGROUND

The U. S. Army Recruiting Command (USAREC) is responsible for recruiting civilians to enlist into the Army. The Department of the Army (DA) specifies the number and quality of civilians that USAREC must enlist annually. In past years, DA required approximately 76,000 recruits to access (enter) into the Army. Of these recruits, at least 95% had to be high school graduates, at least 14% had to be female, and no more than 4% could have prior military experience.[1]

To accomplish this mission, USAREC has five brigades covering all fifty states and several overseas locations. Each brigade has approximately eight battalions, and each battalion has four to six recruiting companies. The recruiting companies have recruiting stations spread throughout the local area to do the actual recruiting.

USAREC divides the DA mission into monthly and quarterly goals. The monthly mission is passed through the brigades, battalions, and companies, down to the recruiting stations. Prior to 1994, each recruiter would be assigned a mission or quota. USAREC changed this policy in 1994, and now assigns the mission to the recruiting station to reduce the pressure on the individual recruiter. Each recruiting station is responsible to meet the monthly and quarterly recruiting goal.

The Army recruiter must perform duties much like a salesperson by selling the Army to American youths primarily between the ages of 17 and 21. These recruiters begin by making contacts with youths at high schools, recruiting stations, or through informal

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[1] These numbers were extracted from a thesis proposal written by CPT Burris, US Army, dated 26 March 1993.

introductions. The recruiters must encourage enough individuals to enlist in the Army so that the recruiting station meets its monthly quota.

New recruits do not go into the Army immediately. Normally, new recruits enter the Delayed Entry Program (DEP), a system that allows the Army time to conduct a security check of the individual and to have the new recruits report to basic training when training seats are available. Because the recruit is not officially in the Army until he or she begins basic training, there may be a delay of one to six months after signing the contract. It is the recruiter's responsibility to ensure the prospect stays eligible for military service.

The recruiting process has not changed significantly since the draft was eliminated over twenty years ago. In 1973 there was concern about how the services would fare after the draft was eliminated. The military had to offer better "packages" to draw potential recruits away from civilian industry. Because of this, the quality and quantity of the new recruits was determined in part by the state of the economy and the incentives offered to recruits. Popular incentives offered to recruits in the past were education benefits, skill training, shorter enlistment periods and enlistment bonuses.

Although recruiting incentives have focused primarily on benefits to draw new recruits, the recruiters also have incentives to meet their mission. All recruiters are paid a monthly allowance between $165 and $275 because of the difficult conditions in which they must work. Additionally, the current incentive program includes a series of badges that the recruiters can earn for outstanding performance in recruiting. The biggest incentive for recruiters is the recruiters ring. The recruiter who has earned this ring is recognized as one of the top recruiters in the Army. These incentives, though, do not necessarily encourage recruiters to exceed their mission or maximize the recruiting market.

An alternative incentive structure to the current one was proposed by Professors Terasawa and Kang of the Naval Postgraduate School. The Bonus Incentive Recruiter Model (BIRM) was briefly discussed in an NPS thesis titled *U.S. Army Recruiting: A*

Critical Analysis of Unit Costing and the Introduction of Recruiting Bonus Incentive Model by Lyons and Riester (1993). One of the conclusions of this work was the current system appears to have inefficiencies that could be denying USAREC from achieving its full potential. The market may allow USAREC to contract many more recruits than the assigned quota, but because the recruiters have no incentive to overproduce, this potential windfall of recruits is "backpocketed." The recruiters will backpocket recruits only if the probability of leakage is low. Leakage is defined as backpocketed recruits that decide not to enlist in later months.

One may ask why the Army should consider a different incentive structure if the recruiters are meeting their manpower goals. Many people believe in the adage, *"If it isn't broken, don't fix it!"* The first reason for exploring this incentive structure is cost. The Army recruiting goals fluctuate from year to year. This past fiscal year (FY), the Army had to recruit about 68,000 people but for FY 95, USAREC is expecting a mission of over 90,000 people. This 22,000 increase in the mission can be accomplished in one of three ways: 1) Hire more recruiters, 2) Get more out of the current force structure, or 3) A combination of 1) and 2).

Secondly, a different incentive structure could produce other positive benefits. Perhaps the recruiters will feel that USAREC is more appreciative of their work, and would therefore have a better, more positive outlook towards recruiting. A positive attitude, essential for any salesperson, is especially important for Army recruiters since they are the first real contact many civilians have with any of the services. A different incentive structure could even lead to more non-commissioned officers (NCO's) volunteering for recruiting duty rather than being forced into it. Volunteers are normally easier to motivate and usually possess the "self-starter" quality that is critical in a salesperson's job.

B. CURRENT INCENTIVE SYSTEM

The current incentive structure does not encourage the recruiters to produce more than their "fair share" of the recruiting station's quota mission. In the past, one of the primary reasons recruiters produce only their quota was to avoid bad evaluation reports. At all levels of USAREC, the recruiting stations are closely monitored to ensure they meet their monthly quota. If a recruiter met his monthly quota, then he was deemed successful. Since success was measured monthly, any extra recruits the recruiter had would be held for the following month.

The same mentality that prevailed when the recruiters had individual quotas prevails for the recruiting stations since the recruiters have no incentive or motivation to achieve above and beyond their station mission. If a recruiting station has met its monthly quota, then any extra prospects would be held for a future month. Although the Recruiting Command headquarters discourages this practice, there is nothing that prevents it from happening.

This practice is prevalent because the recruiting process is a continuous cycle. The station receives a new quota and the recruiters strive to meet it during that month. As soon as the station meets its mission, the recruiters shift their attention to future months. The station's, and hence the recruiter's performance, is based primarily on his ability to meet the mission, not necessarily to exceed it. This continuous monthly cycle creates an atmosphere for the recruiter to hold any extra prospects until the following month. This practice is known in the recruiting business as "backpocketing," because the recruit is held in the recruiters back pocket until he is needed for the next recruiting mission.

The Bonus Incentive Recruiter Model (BIRM) should reduce the number of recruits that are backpocketed because it provides an incentive to the recruiter to process any recruits he "holds" into the service. Section III. C explains in detail the BIRM and how it motivates the recruiters to produce as many recruits as their region will allow.

C. THE BONUS INCENTIVE RECRUITER MODEL (BIRM)

1. Introduction

In the BIRM incentive structure the recruiter, like the card player in the game of *Spades*[2], must forecast his performance over a specified period of time (monthly or quarterly), and at the end of this period, the actual results are tabulated. The key to this incentive model is linking the recruiter's market forecast to his actual production. The recruiter goes to the bonus table and aligns his actual production with his forecast to determine his bonus for that period. Under this system, the recruiter would be rewarded based on how accurately he forecasts his production. The higher and more accurate the forecast, the higher the recruiter's reward will be. The best payments in the bonus table are along the diagonal where the forecast equals the production. If the time period were monthly, then the process would be:

a. The recruiter forecasts the number of people he will contract for the month.

b. The recruiter recruits for that month.

c. The recruiter's actual performance is compared to the forecast.

d. The bonus table is used to determine the bonus payment for his recruiting efforts.

2. BIRM Model Highlights

The bonus incentive model is an alternative to the current quota system. The highlights of the BIRM incentive model are as follows (Lyons and Riester, 1993):

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[2] The BIRM incentive structure is very similar to the card game *Spades*. *Spades* is normally played by two teams of two players. Each player on each team is dealt thirteen cards, and then estimates the number of books (or tricks) they can make from their hand. Then as a team, the two members estimate the total number of books they will make. A book is won by having the highest card of the suit that led the current play. The game is called *Spades* because spades are considered the trump suit, or the suit that defeats any other suit. The strategy of the game is to bid your hand as close to the actual number of books you win. If you underbid, you do not achieve the maximum number of points for the round. If you overbid and fall short of your bid, then you lose points from your score.

a. It provides an incentive for recruiters to surpass quotas and thereby maximize the true market potential.
b. It rewards recruiters with monetary bonuses based on their work effort and their ability to forecast.
c. In the long run, it rewards recruiters equitably despite regional market differences.
d. It will provide, in the long run, valuable market information to the USAREC headquarters that will allow efficient future resource reallocation to the productive regions.
e. It will help reduce the recruiter's tendency to delay or hold applicants for future months thereby improving market information to the USAREC Headquarters.
f. By changing the bonus table, the model is adjustable to reflect changing Army accession requirements.
g. The model is capable of maintaining quality marks.

D. PURPOSE OF THE STUDY

The purpose of this thesis is to provide USAREC with some background material on developing the bonus table and to provide preliminary estimates of the effects of the BIRM on recruiting. Since this incentive structure has not been field tested, it is critical to accurately understand the possible outcomes, advantages, and shortcomings if it were implemented. The use of computer simulation techniques will be used to help understand the BIRM and its impact. In the process of conducting this analysis, other complementary issues concerning the BIRM will be examined, such as how USAREC will meet its Army-wide accession requirements.

II. LITERATURE REVIEW

A. RELATED STUDIES - BONUS TABLE ANALYSIS

The first section of this thesis is an analysis of developing the bonus table for the BIRM. The bonus table is the compensation that USAREC gives to the recruiters for forecasting and producing a certain number of recruits. There are many books that deal with compensation management. Henderson (1982) discusses compensation management in great detail and provides insight into the difficult issues that should be addressed when establishing performance based rewards. He also gives a detailed analysis of how behavioral science concepts need to be considered to account for the human psyche issues. Although Henderson wrote his book in the context of industry, the discussion is applicable to the military since USAREC is in the "business" of selling the Army to American youths.

B. RELATED STUDIES - RECRUITER INCENTIVES

USAREC has an umbrella agreement with the Naval Postgraduate School to conduct research on some of their most pressing problems. Much of the previous research dealt with increasing the efficiency of the recruiting effort. Additionally, because recruiting issues affect all of the services, there have been several theses that have dealt with the recruiting practices and problems in the Navy.

The thesis written by Lyons and Riester builds the framework for the BIRM model and addresses the question of whether or not changing the incentive structure would make an impact. Their thesis focused on the inefficiency caused by the quota system, and they showed that the recruiters could produce better results than the quota system.

This thesis will differ from their work in that an analytical approach will be developed to assist USAREC in determining the effects of the BIRM. Additionally, this thesis will discuss the development of the bonus table, which is a critical component of the BIRM.

Lewis (1987) examined the influence of environmental factors on recruiting categories I - IIIA[3]. Factors such as unemployment rates, geographic region and other environmental elements were found to significantly affect the number of contracts achieved by the recruiter. This study is relevant to the current thesis because it showed that there are factors outside of USAREC's control that affects the recruiter's productivity and should be considered in the model to help better simulate the recruiting process.

In *Navy Recruiter Productivity and the Freeman Plan*, a study conducted by the RAND corporation for the Navy, Asch (1990) concludes that the Navy's incentive program could, in some circumstances, motivate the recruiters to *not* perform their best and may have also encouraged recruiters to enlist lower quality people, contrary to the Navy's recruiting goals. Asch's study provides valuable insights into some of the psychological issues of recruiting which are incorporated into our model through the derivation of the recruiter's utility function.

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[3] The Army considers categories I - IIIA to be high quality candidates for enlistment and the designation is based primarily on the results of the Armed Forces Qualification Test (AFQT) and the recruit's high school graduation status.

III. BONUS TABLE DEVELOPMENT

A. INTRODUCTION

Before attempting to generate a model for the bonus table, several preliminary issues must be addressed. The first building block for the model is identifying the appropriate number of new recruits that the recruiters much achieve in order to start earning the bonus. The second building block is the determination of how to change from one prediction/production level to another. Finally, the base payment vector must be established to calculate the rest of the table. These three elements will be used to develop the bonus table.

B. PRELIMINARY ISSUES

1. Minimum Recruits Needed to Enter Bonus Table

This section discusses the minimum number of recruits the recruiter must access in order to start earning the bonuses. It is important that the incentives appear fair to all recruiters, regardless of the type of market they are working in. If the recruiters view the initial level as reasonable, then the recruiters will provide USAREC with important information about the local recruiting market. If the local market is good and the bonus table is satisfactory, then the recruiter's forecast will provide USAREC with valuable information on the current recruiting climate. If the market is not good, then the recruiter's forecast will be lower but it still provides USAREC with information on the local market. An example illustrates the critical nature of this information.

a. An Example Illustrating Why a Minimum Threshold Must Be Set

Suppose the starting recruiting level for the bonus is two new recruits per month. For the recruiter who works in a dense population center (like New York City),

producing even four recruits may not be too difficult. The four-recruit level could even be less than the production that was expected under the old quota based system. This recruiter would forecast four or more, since he was producing more before. This recruiter would find that using the bonus table would be easy.

Contrast the previous recruiter with one based in a less dense population area (such as Nebraska). This recruiter could have been hard pressed under the old quota system to produce two recruits per month, and it would probably be more difficult for him to reach the threshold of the bonus table because of the environment.

The starting level of the number of new recruits for the bonus table is critical. USAREC must set the level high enough to make a recruiter work and forecast accurately while at the same time set it low enough so that recruiters feel that it's fair and achievable. The example above seems unfair to one recruiter and advantageous to the other. The recruiter in New York City would be happy to have the table start at two recruits because then he could enter the bonus table with a minimum of extra work. On the other hand, the recruiter in Nebraska would probably have to work harder to exceed the minimum required level.

In the short run, the recruiters may not be on level ground. However, the recruiters who use the bonus table provide the type of information that will help USAREC allocate the next recruiter, because then USAREC knows where the market is rich. Along with other relevant marketing information, USAREC can decide where to allocate more recruiters.

b. A starting point for establishing the minimum required recruit level

The national historical production level (NHPL) could be a basis for a starting point for establishing the minimum required recruit level. The NHPL is the average number of recruits that the recruiters have produced over the year. Production data from USAREC indicated that each recruiter averaged about 1.29 recruits per month in FY 94. If the recruiting station was historically producing above the NHPL, then the

recruiters in that station would have a better chance of entering the bonus table. If, however, the station were located in an area where the local production level was less than the NHPL, then the recruiters would find it more difficult to enter the bonus table.

C. BASE TABLE ALGORITHM

The bonus table must reward more accurate and higher levels of the forecast. In order to do this, the bonus table has to tie the recruiter's forecast to his actual production. The following algorithm was developed for this thesis, and is one way that the recruiter's forecast can be tied to his production. The base table is used to change from one prediction/production level to another.

First, the variables used in building the base table are defined:

Let p = the forecasted number of recruits by the recruiter

k = the actual production of the recruiter

B_{pk} = the base value for forecast p and production k

Base Payment Vector (BPV) = the base payments in the bonus table when the forecast equals the production

$$B_{pk} = \begin{cases} (p-k)/p & \text{if } p > k \\ (k-p)/k & \text{if } p < k \\ 0 & \text{if } p = k \end{cases} \tag{1}$$

Table 1 shows the values for B_{pk} for forecasted and production values between one and five. The base table is used to change the recruiters bonus payment when he does not forecast his production accurately.

As the recruiter's production deviates from his forecast, only a percentage of the next step is subtracted or added to the BPV. The step is defined as the incremental jump of the payment in the BPV. For an example, if the payment for forecasting one and producing one is \$50, and the payment for forecasting two and producing two is \$75, then the step is the difference in the two payments, or \$25.

		Prediction (p)				
		1	2	3	4	5
Production (k)	1	0.00	0.50	0.67	0.75	0.80
	2	0.50	0.00	0.33	0.50	0.60
	3	0.67	0.33	0.00	0.25	0.40
	4	0.75	0.50	0.25	0.00	0.20
	5	0.80	0.60	0.40	0.20	0.00

Table 1 Base Table (Values of B_{pk})

D. BONUS TABLE DEVELOPMENT

The BPV is the vector of payments that are used to calculate the bonus table. The base vector are the payments in cells (1,1), (2,2),...(p,k), where the first number indicates the prediction level and the second number represents the actual production of the recruiter. Determining these payments is discussed later in this section. Together with the base table, a complete bonus table can be formed.

1. Preliminary Bonus Table Analysis

In order to help understand how the values in the table should compare to one another, an analysis of a portion of the bonus table is conducted. Table 2 is a (3 x 3) bonus table with A_1, B_1, C_1, and D_1 substituted for actual bonus payment values.

In order to meet the objective of rewarding more accurate and higher forecasts, the payments in the table must increase in the following order: $B_1 < A_1 < C_1 < D_1$. Payment B_1 is the payment when the recruiter predicts two but produces one, so the recruiter is penalized for falling short of the forecast. If the recruiter produced two when one was predicted (C_1), then the payment would be greater than if he had predicted one and

produced one (A_1). However, the recruiter could have maximized the bonus if he had accurately forecasted two recruits (D_1).

Prediction (p)

Production(k)		1	2	3
	1	A_1	B_1	
	2	C_1	D_1	
	3			

Table 2 Bonus Table Analysis

By shifting the payments in Table 2 one column to the right, some additional insight can be gained on the magnitudes of the bonus payments. Suppose the payments are as shown in Table 3 below. For this example, the payments should fall in the following order: $B_2 < A_2 < D_2 < C_2$. Payments B_2 and C_2 are straight-forward in their relative placement to the other payments. D_2 should be greater than A_2, even though both fell short of the forecast by one, because D_2 had a higher forecast and production.

Prediction (p)

Production(k)		1	2	3
	1		A_2	B_2
	2		C_2	D_2
	3			

Table 3 Bonus Table Analysis

2. Bonus Table Calculations

The bonus table amounts were calculated using the following formula:

Let X_{pk} = base payment amount for prediction p and production k. This payment is located in the bonus table when the production (k) equals the forecast (p).

Let Y_{pk} = bonus payment.

$$
Y_{p,k} = \begin{cases} Y_{p,\,k-1} + \prod_{t=p+1}^{k} B_{pt}\,(X_{k,k} - X_{k-1,k-1}) & \text{if } k > p \\ Y_{p-1,\,k} - (1 - \prod_{t=k+1}^{p} B_{tk})(X_{p,p} - X_{p-1,p-1}) & \text{if } p > k \\ X_{p,k} & \text{if } p = k \end{cases} \tag{2}
$$

If $\text{BPV} = \begin{bmatrix} 50 \\ 75 \\ 100 \\ 125 \\ 150 \end{bmatrix}$, then the bonus table shown in Table 4 can be produced from the base table (Table 1).

		Prediction (p)				
		1	2	3	4	5
Production (k)	1	50.00	37.50	20.87	2.16	0.00[4]
	2	62.50	75.00	58.50	37.63	15.10
	3	70.88	83.25	100.00	81.25	58.75
	4	77.16	87.38	106.25	125.00	105.00
	5	82.18	89.85	108.75	130.00	150.00

Table 4 Bonus Table

E. BONUS TABLE ANALYSIS

In order to adequately analyze the bonus table, we should first analyze the base table, since the bonus table is derived from the base table. The base table is a tool to adjust the

[4] If the bonus table value was less than zero when Equation 2 was applied, then the bonus table value was set to zero.

recruiter's reward, either a positive amount for exceeding the forecast, or a negative amount for falling short of the forecast. Figure 1 is a graphical representation of Table 4, with a negative sign in front of the value if the recruiter's production was less than the prediction. In this format, it is easier to see that the recruiter incurs a penalty whether he overproduces or underproduces relative to the forecast. The recruiter's penalty for overproducing is the opportunity cost of foregone payments. Had he forecasted at the actual level produced, then he would have earned more. Thus, the recruiter receives only a portion of the highest possible payment for that level of production.

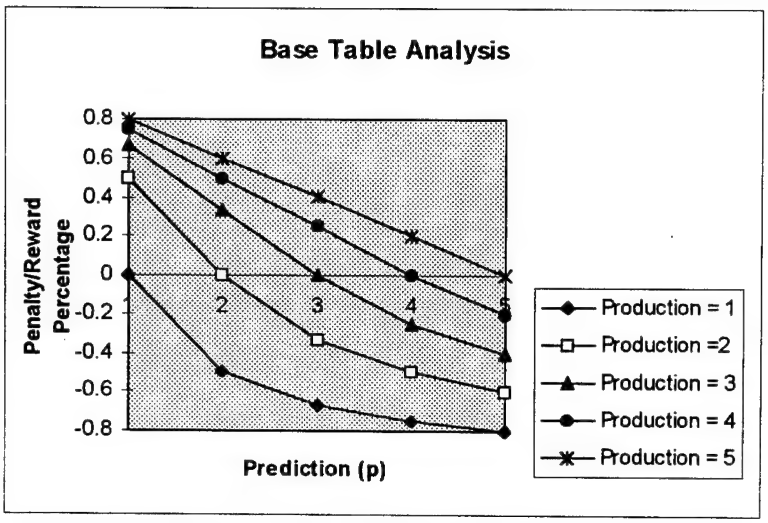

Figure 1 Base Table Analysis

Notice that the curves are steeper at lower production levels than at higher levels. The recruiter's marginal return gets smaller as the recruiter overproduces. The intention of developing the table this way is to provide the motivation to the recruiter to accurately forecast production. If the lines in the graph are above y = 0, then the recruiter has overproduced, and if the line is below y = 0 , then the recruiter has underproduced.

The bonus table must provide an incentive for the recruiters to predict accurately and at the highest level possible. Figure 2 shows the marginal increase that the recruiter receives for higher forecasts with a given level of production. This figure is the bonus

table, with each connected line being the recruiter's production level. The points on the highest line are the payments for producing five recruits when the forecast was 1, 2, 3, 4 or 5. The highest payments for the recruiter at any given production level is when his forecast equals his production. Notice, though, that the recruiter is not penalized the same amount for each shortfall. For instance, the percentage loss from predicting three and producing two is less than if the recruiter predicted two and produced one. (42% loss versus 50% loss). Therefore, the recruiter incurs a higher penalty for a shortfall at lower forecasts rather than at higher forecasts.

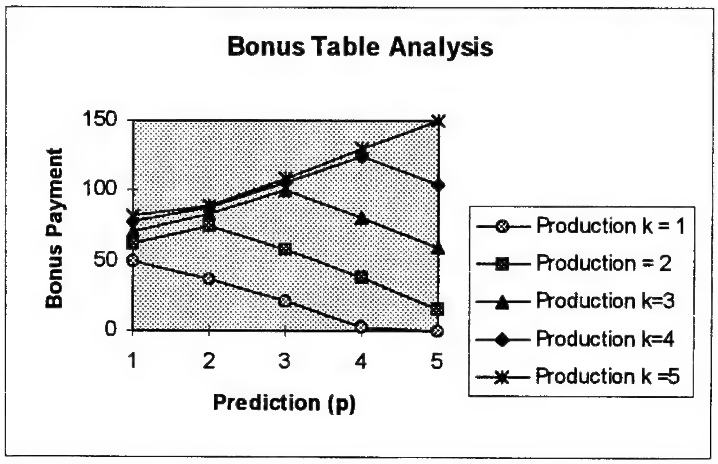

Figure 2 Bonus Table Analysis

F. AT WHAT DOLLAR AMOUNT SHOULD PAYMENTS START?

Because the base table algorithm was used to develop the bonus table, the analysis on the bonus table would be the same whether the base vector started at $75 or if it started with $20. The natural question that arises is "Where should the payment start?"

1. Utility Theory Considerations

The recruiter's utility for money is one factor that must be considered for the base payment vector (BPV). If the BPV is set too high or too low, then the expected results could be far different from the actual results. If the BPV was too high, then the incentive costs could exceed the predicted costs if more recruiters use the BIRM than expected. If

the BPV is too low, then the expected number of new recruits could fall short because the recruiters do not believe the bonus payment is worth their time and effort. Section IV. B discusses utility theory in more detail as well as how recruiters view the bonus payments.

2. Incentive Program Budget

Another important factor when developing the BPV is the budget for the incentive program. The incentive program must produce the right number of recruits within the budget for it to be considered a success. For this analysis, the costs and expected gains (in recruits) will be estimated through the simulation.

USAREC has two options with regards to the cost. They can maximize the number of recruits within cost x, or they can minimize the cost for y recruits. Since the Army must meet its manpower requirements, USAREC would presumably try to minimize the cost for y recruits. This objective will be transformed into a measure of effectiveness for the simulation.

IV. MODELING THE RECRUITER'S DECISION

A. MODELING USING DECISION THEORY CONSTRUCTS

1. General

The recruiter must decide which prediction level he should make based on the bonus table and the local recruiting environment. This decision process will be modeled first under decision theory constructs. The recruiter's decision will affect the effort he will put forward, and ultimately affect the payoff received. An influence diagram for the recruiter's decision problem is shown in Figure 3. The influence diagram graphically depicts the factors that affect the recruiter's decision, and the events are placed in chronological order from left to right. As shown in the figure, the bonus table affects the recruiters forecast, the number recruited, and the resulting bonus payment.

The influence diagram shows that once the bonus table is developed, the recruiter must make a decision on what amount to forecast. This decision affects the number that the recruiter recruits and the payoff received. Since the recruiter forecasts his production, the recruiter should be expected to strive toward achieving this amount. His decision also affects the payoff, since the bonus payment the recruiter receives is a function of the forecast (p) and production (k).

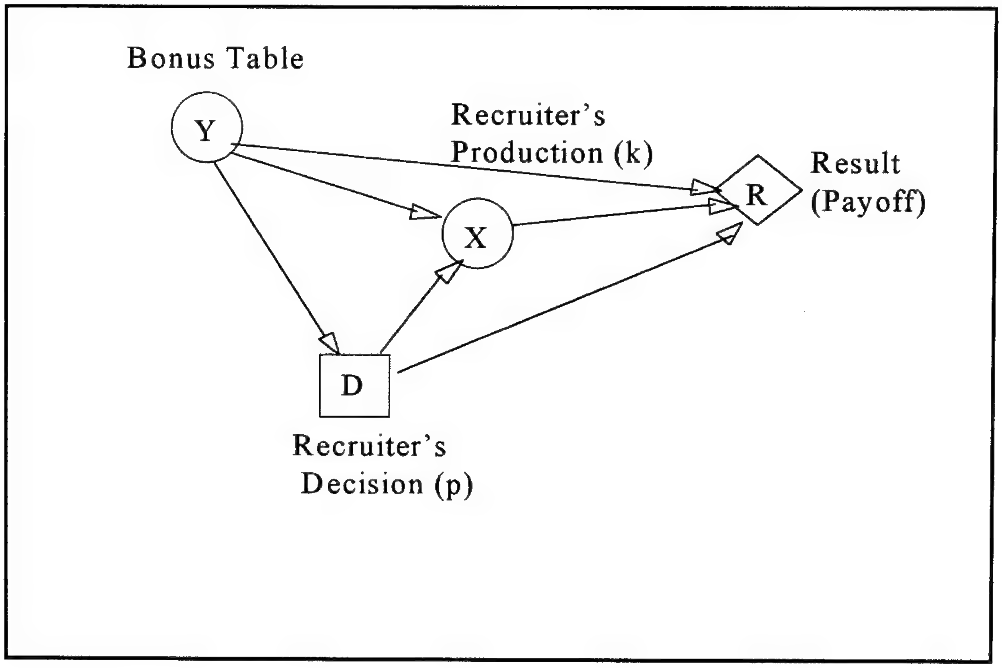

Figure 3 Influence Diagram of Recruiter's Decision

2. Analysis of the Recruiter's Decision

An easy way to see the decisions that the recruiter has to make is through a decision tree. The decision tree for the recruiter's situation is shown in Figure 4 below. The two branches coming from the "*Y*" node are the payments USAREC can set for the bonus table. The sweeping arcs indicate that USAREC has an infinite number of payment vectors it can make.

The *Y* node connects to the *D* node, which is where the recruiter makes his forecasting decision. The branches from the *D* node are the choices the recruiter can make for forecasts. Like the bonus table, there are an infinite number of choices the recruiter can forecast, so the branches go from zero to *n*.

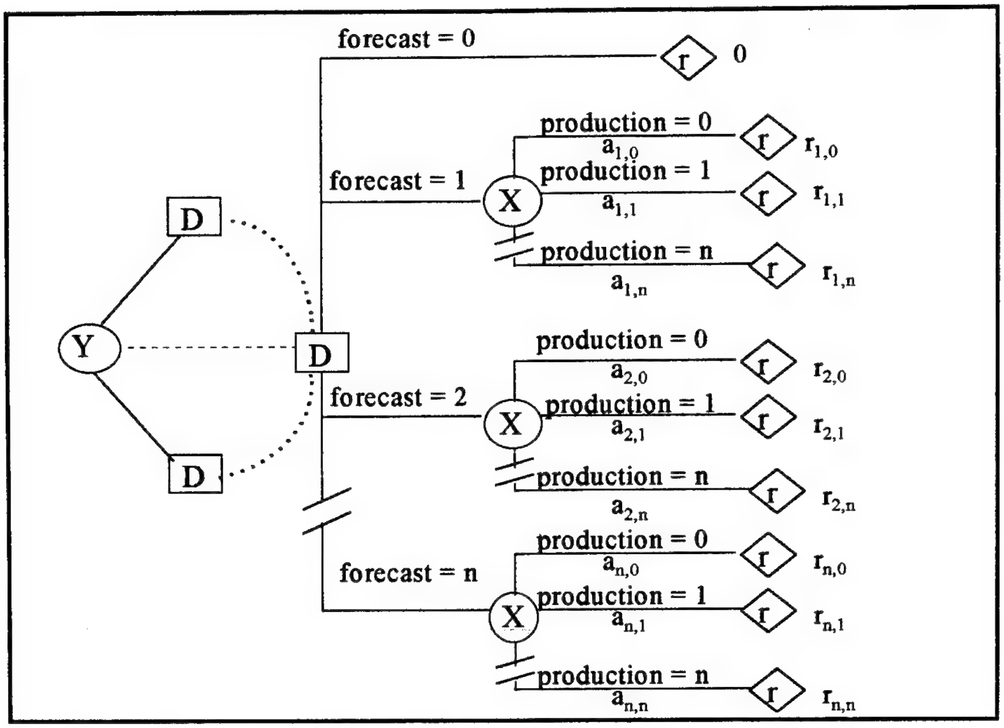

Figure 4 Recruiter's Decision Tree

If an assumption is made that each recruiter must produce at least one recruit per month, then the first branch is not needed. For the other branches, the *X* node represents the random variable of the actual number of recruits produced. The diagram shows there is no upper bound on the number of recruits the recruiter could produce. To simplify our problem, the number of branches has been limited by assuming that the vast majority of the recruiters will produce recruits in the range of (-2,-1, 0, 1,2) of their forecast.

The probabilities on the branches, α_{pk}, are the conditional probabilities that the recruiter produces *k* recruits, given the recruiter has forecasted *p*. For an example, α_{22}, represents the probability that the recruiter produces two given that he has forecasted two.

If the recruiters made their decision based on expected values, then the recruiter decision problem can be stated as:

$$\underset{0 \le p \le n}{Max} \sum_{\forall k} \alpha_{pk}\left(r_{pk}\right) \qquad (3)$$

r_{pk} is the bonus payment set by USAREC, and α_{pk} must be estimated.

This problem can be solved only when the market information is known. For instance, if a market could only produce two recruits, then the recruiter would not be expected to forecast five recruits. For this analysis, the recruiter is assumed to be aware of the number of recruits that his market could support.

4. Solution using Decision Theory

The solution to this decision problem is determining what forecast the recruiter should make, given he knows the market conditions. A market that will support one recruit per month is analyzed first.

Suppose the data shown in Table 5 was known. The table shows the recruiter's forecast, production and bonus payments. Also estimated is a probability of production level *k*, given the market.

Forecast	Production	Bonus Payment	P(Production = p| market=1)	Expected Value
1	1	50.00	.80	52.50
	2	62.50	.20	
2	1	37.50	.80	45.00
	2	75.00	.20	

Table 5 Hypothetical Data for One-Recruit Market

Eighty percent of the time the recruiter will produce one recruit when the market supports one recruit, and the recruiter produces two recruits twenty percent of the time. The expected payoffs for forecasting one and two recruits are \$52.50 and \$45.00, respectively. If the recruiter based his decision on expected payoffs, then he would forecast one to maximize his return.

The indifference probability is the probability when the recruiter is indifferent to choosing one forecast or the other, because they produce the same result. It can be obtained by setting the expected value equations equal to each other, with p and $1-p$ substituted as the probability of producing one and two recruits, respectively. Equation 4 finds the indifference probability for the one-recruit market.

$$50\,p + 62.5\,(1-p) = 37.50\,p + 75\,(1-p) \tag{4}$$

Solving for p yields an indifference probability of 0.50. If $p > 0.50$, then the recruiter should forecast one recruit. If the recruiter believes he can achieve two recruits more than fifty percent of the time, then he should forecast two recruits. If he believes either one or two recruits could equally be the outcome, then it does not matter which forecast he makes.

Table 6 is a summary of the two-recruit market. The assumption for this table is that twenty percent of the time the recruiter produces one recruit and eighty percent of the time he produces two recruits, then the recruiter's expected payoff would be $60.00 if he forecasted one recruit, and $67.50 if he forecasted two recruits. If the recruiter wants to maximize his expected return, then he should forecast two recruits.

The indifference probability for this scenario is also 0.50. If the recruiter believes that the market will produce two recruits more than fifty percent of the time, then he should forecast two recruits.

Forecast	**Production**	**Bonus Payment**	**P(Production = p| market=1)**	**Expected Value**
1	1	50.00	.20	60.00
	2	62.50	.80	
2	1	37.50	.20	67.50
	2	75.00	.80	

Table 6 Hypothetical Data for Two-Recruit Market

The previous two examples made a simplifying assumption that the recruiter would produce only one or two recruits. This analysis is expanded to include three production levels.

Suppose the data shown in Table 7 was known. In this three- recruit market, twenty percent of the time the recruiter produces two recruits, sixty percent of the time he

produces three recruits, and 20 percent of the time he produces four recruits. By using the expected values for the three forecasts, the recruiter should forecast three recruits to maximize his expected payoff.

An indifference probability for this problem cannot be found since there are three alternatives. However, if an assumption is made that producing two or four recruits are equally likely, then the best payoff is always when the recruiter forecasts three. Since the BIRM exposes the true-market potential, the recruiter should forecast what his market will allow.

Forecast	Production	Bonus Payment	P(Production = p| market=1)	Expected Value
2	2	75.00	.20	82.47
	3	83.33	.60	
	4	87.38	.20	
3	2	58.50	.20	92.95
	3	100.00	.60	
	4	106.25	.20	
4	2	37.63	.20	81.28
	3	81.25	.60	
	4	125.00	.20	

Table 7 Hypothetical Data for Three-Recruit Market

B. RECRUITER'S DECISION USING UTILITY THEORY

1. General

Utility theory and decision making can be traced back to Nicolas Bernoulli. Bernoulli's St. Petersburg paradox was a game that dealt with the utility value of money. The player would pay an amount up front to play the game. The prize to the player would be determined by flipping a coin. The payment is based on the number of times "heads" came up before the first "tail." If the number of times that tail occurs is x, then the payoff would be 2^x. Bernoulli's research showed that people were not likely to pay a lot to play the game, even though it was shown to have an infinite return.

In an attempt to find a solution to the St. Petersburg paradox, Nicolas Bernoulli posed the paradox to his younger cousin, Daniel Bernoulli. Daniel Bernoulli reasoned that the value, or utility, of money declined with the amount won (or already possessed). This observation set the stage for the later theories of choice behavior. (Plous, 1993).

John von Neumann and Oskar Morgenstern proposed expected utility theory in 1947 as a normative theory of behavior. They intended expected utility theory to describe how people would behave if they followed certain requirements of decision making, not how people actually behave. Expected utility theory can be used as a base to compare behavior of real decision makers, and its simplicity has made it a popular model for decision making.

The axioms of rational decision making are listed below. Most decision making texts contain detailed descriptions of the axioms.

(1) Ordering of alternatives

(2) Dominance

(3) Cancellation

(4) Transitivity

(5) Continuity

(6) Invariance (Plous, 1993)

2. Applying Utility Theory to the Recruiter's Decision

The marginal return of extra money to the recruiter is expected to decrease as the recruiter receives more money. Graphically, the utility function would then take the form shown in Figure 5.

The payoff, d, is directly related to the number of recruits (k) that the recruiter produces. The recruiter's utility can be expressed as $U(f(k))$, where $f(k)$ is the bonus table payoff for k recruits.

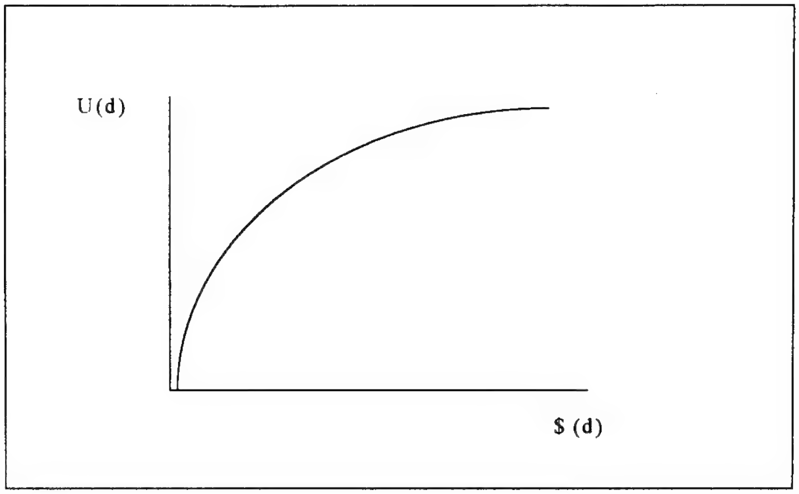

Figure 5 Recruiter's Utility Function

The recruiter also incurs a cost for producing recruits. Although the cost function could be included in the recruiter's utility function, it is shown explicitly to add emphasis to its significance. Figure 6 shows the graph of the cost function. Intuitively, the cost curve is expected to have this shape since the effort the recruiter puts forward should increase as more recruits are produced. The x-axis in the figure has the units of recruits per unit time, but for simplicity, it will be referred to as the recruiter's production *k*.

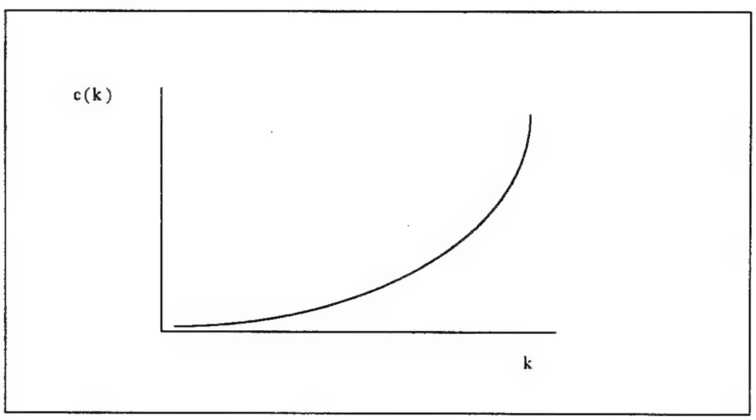

Figure 6 Recruiter's Cost Function

The cost function *c(k)* is a subjective cost that the recruiter feels he has to pay to get *k* recruits. This cost is measured by the value the recruiter places on his time and energy, and has the same units as the utility function.

3. Non-Linear Program and Solution to the Recruiters Decision

For a single recruiter, the recruiter's decisionmaking problem can be stated as the following non-linear program:

$$\begin{gathered} MAX\ U(f(k)) - c(k) \\ Subject\ to:\ k \geq 0 \end{gathered} \tag{5}$$

If k can be modeled as continuous, then the approximate optimal solution to this problem can be found by differentiating the objective function with respect to k. If the functions are assumed to be well behaved, then:

$$U'(f(k))f'(k) = c'(k) \tag{6}$$

Graphically, the solution would be the maximum point on the curve. p versus *U(f(k))-c(k)* is plotted, the graph would look like Figure 7. The solution, p^*, is the value that the recruiter should predict.

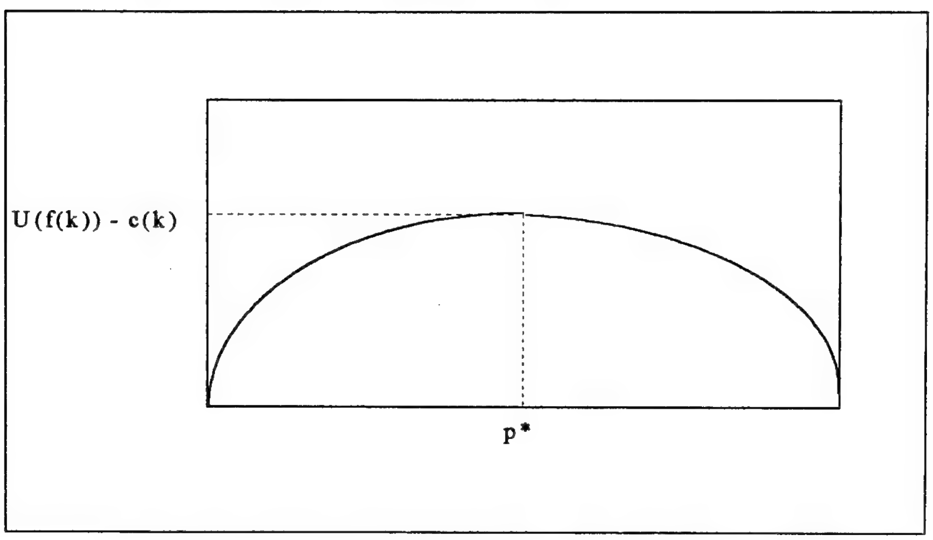

Figure 7 Graphical Solution to Recruiter's Decision

V. SIMULATION

A. GENERAL

A computer simulation was developed using Turbo Pascal® that generates utility and cost curves for recruiters, forecast and production levels for the recruiters, and a bonus table. The results are then aggregated to form a representative recruiting station. A copy of the Turbo Pascal® code for this simulation is included in Appendix B. A copy of the output results is included in Appendix C.

B. MEASURES OF EFFECTIVENESS (MOE)

Before the simulation is constructed, the criteria for comparing the BIRM model with the old quota-based system must be established. The two MOEs used in this paper are the time to completion (TTC) for the recruiting year, and the estimated cost under the two incentive structures. The first MOE is the time in months that it takes USAREC to complete its recruiting mission. Assume under each incentive structure is the recruiting command has 4,200 recruiters available. The TTC under the quota system can be estimated by analyzing the historical data on production. The TTC value for the BIRM will be estimated through the simulation. The smaller the TTC, the better it is for USAREC since the goal is met earlier in the recruiting year.

The second MOE is the estimated cost for recruiting an additional 22,000 recruits. This MOE is used because USAREC stated that they were increasing the number of recruiters to almost 5,000. This MOE will be used to determine what difference there is between adding the additional recruiters or using the BIRM incentive structure. The number of additional recruiters can be estimated by using the historical production rate. The cost of these additional recruiters can be estimated by multiplying the special duty

payment that the Army pays to the recruiters for being assigned to recruiting duty, by the number of additional recruiters. Although there are probably other costs that the Army incurs by assigning someone to recruiting duty (such as training costs), the special duty pay is assumed to be the only relevant cost for this analysis.

The simulation estimates the total cost of recruiting these additional recruits under the BIRM system. The recruiter's forecast and prediction are used to enter the bonus table, and then the payments are combined to determine the total cost under the BIRM. This cost is compared to the total cost under the quota system to determine the better performer. A lower cost would be better under this MOE.

C. SIMULATION CONSTRUCTION

Once the MOEs are understood, the computer simulation is tailored so that it provides the information needed to test the BIRM versus the quota system. The computer simulation can be separated into three main components - program initialization, recruiter force aggregation, and an algorithm that outputs the data for the measures of effectiveness.

1. Initialization

The program initialization can be divided into two parts. The system drop-through initializes the simulation parameters. The program is run many times, but most of the initialization parameters do not change. Mean values for the utility and cost functions are established, but the program chooses the actual values by drawing them from a distribution. A recruiting level that must be achieved is also specified, and the time to complete this mission is used as one of the measures of effectiveness.

The second part is the development of the key sub-systems of the BIRM model. The first procedure develops the bonus table as discussed in Section III. D. The program uses the base payment vector specified by USAREC and then calculates the rest of the

table. After the bonus table, the program develops the utility and cost functions for each recruiter.

2. Utility and Cost Functions

Among many utility functions described in decision making texts, the following well-known function was chosen to model the recruiter's utility function (Marshall and Oliver, 1995):

$$u(x) = \frac{\log\left[1 + (B-1)(\frac{x}{\theta})\right]}{\log B} \qquad B > 1 \qquad (7)$$

B and θ are the two parameters that uniquely define each utility function. B is a shape parameter that increases or decreases the magnitude of the utility. The graph of Equation 6 has the shape shown in Figure 5. This function models the utility the recruiter derives from a certain amount of money (x). The x values used in the simulation are the base payment vector from the bonus table development. Table 8 shows numerical values of u given the BPV, and how the value of the utility changes with values of B.

x	B=3, θ= 3	B=8, θ= 3
50	3.22	2.29
75	3.58	2.49
100	3.84	2.62
125	4.04	2.73
150	4.20	2.82

Table 8 Utility Values (B variable)

When B is increased, the range of the utility values decrease from 0.98 (4.20 - 3.22) to 0.53 (2.82-2.29), or, almost half. An analogy of what B does is it acts like a trash compactor. As B increases, the magnitude and range of the utility decrease.

The utility procedure in the simulation program creates the recruiter's utility function by drawing the parameters B and θ from normal distributions. The mean and the standard deviation for the distributions are specified in the system drop-through. After the program draws values for B and θ, it creates unique utility and cost functions for all 4,200 recruiters. Initially for this simulation, the means of B and θ are set to three. The two B values in Table 8 illustrate how B changes the recruiter's utility function. Notice that by increasing B to eight, the utility values start and end at lower values than if B were three.

The second parameter in the utility function, θ, decreases the utility function just as B does. As θ increases, the utility function values decrease.

x	**θ=3, B = 3**	**θ=8, B = 3**
50	3.22	2.37
75	3.58	2.72
100	3.84	2.97
125	4.04	3.16
150	4.20	3.32

Table 9 Utility Values (θ variable)

Although the magnitude of the function is lower, the range of the utility function remains almost constant (0.98 versus 0.95). The θ*'s* impact is expected to be more limited than the B parameter. For this simulation, the B and θ values are initially set to three.

	Mean	Standard Deviation
B	3	1
θ	3	1

Table 10 Parameter Values for Utility Function

The only restrictions on B and θ are that they must be positive, real numbers, and B must be greater than one. The utility function is the first component that is used to estimate the recruiter's forecast. The cost function also is needed to determine what the recruiter will predict.

The cost function used in the simulation has the form:

$$c(p) = \alpha\, p^{\beta} \tag{8}$$

The cost function is defined in terms of the expected cost of producing p recruits. Like the utility function, the cost function has two parameters, α and β. The α parameter determines the initial magnitude of the cost and can be thought of as the cost multiplier.

The β parameter defines the rate of increase of the cost function. As stated earlier, the cost function is expected to take the shape shown in Figure 6. Because of this, the β parameter is expected to be greater than one (linear cost function). The values in Table 11 are used as starting points for the simulation. Later, a test is conducted to see how significant these values are to the model.

	Mean	Standard Deviation
α	0.10	0.05
β	1.60	0.25

Table 11 Parameter Values Cost Function

3. Recruiter's Forecast

The program uses the utility function, the cost function, and the bonus table to determine the recruiters forecast. The bonus table is used to calculate the recruiter's utility for different payments and the program calculates the perceived cost that the recruiter believes he pays for producing his prediction. The recruiter's prediction is determined by the maximum point where the utility exceeds the cost. If the recruiter's utility and cost functions lead the recruiter to predict zero recruits, then the program will assign a forecast of one. This was done because the real world data from FY 94 showed that the recruiters averaged about 1.29 recruits per month, or about four per quarter. The recruiters should predict at least to this level under the quota system. If, however, the utility and cost functions produced higher levels above one, then the program would use that as the prediction level.

4. Recruiter's Production

After finding the recruiter's prediction, the simulation then estimates the recruiter's production, k. The program draws the recruiter's production from a normal distribution with the mean equal to the recruiter's prediction. The normal distribution was based on the quota/production data from USAREC. Appendix D shows in detail the analysis that led to the adoption of the normal distribution for the production function. This assumption is checked by changing the distribution to a Beta distribution.

The recruiter's production is expected to change with the prediction level. For instance, overproducing should occur more often if the recruiter has forecasted one recruit versus four or five recruits. Conversely, underproducing is more likely to occur when the forecast is at higher levels rather than at lower levels. Finally, the majority of the recruiters are assumed to produce at their forecast exactly.

Let the variable Y denote the production and X the forecast. Since the probability distribution $Y|X$ does not have any historical data in which to estimate it the

beta distribution is used to model it. In the absence of data, the beta distribution is often used as a rough model. (Law and Kelton, 1991)

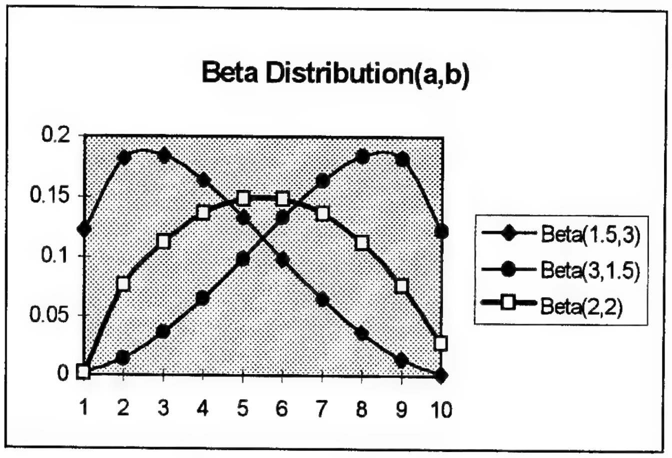

Figure 8 Beta Distribution

As can be seen in Figure 8, the recruiter's production, given that his forecast is known, can be modeled using a beta distribution. For instance, the distribution of Y|X=1 is expected to look more like the Beta (1.5, 3) since the probability of exceeding one recruit to be higher and falling short to be lower. To model a prediction of X=4, the distribution would look more like a Beta (3, 1.5), since more recruiters are expected to fall short of the prediction rather than exceeding it.

Both the normal and the beta distributions are used to model the recruiter's production and an analysis is conducted to determine if production impacts on our MOE. The analysis indicated that the production distribution does impact on both the time to complete the recruiting mission and the cost. Section V. A discusses this result in more detail.

5. Aggregation of Recruiter Forecasts and Production

The final part of the simulation aggregates the individual recruiter forecasts and production into a total recruiter force totaling the predictions and production for the 4,200 recruiters into monthly statistics. These monthly statistics are used to estimate the MOEs discussed previously. The program adds the monthly totals until the time to completion

(TTC) of the recruiting year is determined. Since the TTC usually varies between three and twelve months, the program repeats itself until a point estimate of the TTC is found with 90% confidence. The program does this by calculating the sample variance for the TTCs generated and then checks to see if the variance is within the prescribed bounds. If the TTC variance does not meet the stopping conditions, then the program repeats itself. The program generates new data for the utility and cost functions, determines new prediction and production for each recruiter for each month, and then aggregates the data to test the TTC. The program continues this cycle until the point estimate is within the tolerance.

VI. RESULTS AND ANALYSIS

The results for the computer simulation are in Appendix C. A summary of the simulation results of the BIRM are in Table 11. The variables TTCN and CostN are the time to completion of the recruiting mission and the estimated cost of the BIRM with the recruiter's production modeled as normally distributed. The variables TTCB and CostB are the time to completion of the recruiting mission and the estimated cost of the BIRM with the recruiter's production modeled as a beta distribution. Because the exact values for the parameters in the recruiter's cost and utility functions were not known exactly, each of the four parameters was set to two different values. The simulation was run for all combinations of the parameters, resulting in $2^4 = 16$ runs of the simulation. The results of the 16 runs were averaged to get the values in Table 11. Later in this chapter, a comparison is made for the TTC and cost results to find if there was a significant difference between the normally distributed production and the beta distributed production. Finally, the data was analyzed to determine which parameters were the most significant in the model.

A. NORMALLY DISTRIBUTED PRODUCTION

1. TTCN Analysis

In order to calculate the TTC under the BIRM, the number of recruits that the recruiters had to attain for the year had to be established. As stated in Chapter III, an assumption was made that the recruiters had to produce at least one recruit per month under the BIRM system. If the recruiter produced more than one per month, then he would be eligible for the bonus from the bonus table. Each of the 4,200 recruiters would

produce 12 recruits per year, plus any recruits under the BIRM system. For a 90,000 recruit goal, the recruiters would be required to produce 50,400 recruits, and the remaining 39,600 would have to be produced under the BIRM. The simulation stopped when the recruiters produced 39,600 recruits.

As Table 12 shows, it took an average of 4.45 months to achieve the 39,600 level if the recruiter's production was modeled as normally distributed. The best way to illustrate what 4.45 months means is to show it through a numerical example. If the recruiters concentrated on the requirement of achieving one recruit per month first and then recruited the other 39,600 recruits, then the time to achieve the 90,000 recruit goal was expected to be 16.45 months.

This analysis should not imply that it would take the recruiters sixteen months to complete their mission under the BIRM. The recruiters will be producing additional recruits for the bonus payment as they meet their minimum requirement for the month. The 4.45 months is only an estimate to achieve the 39,600 recruits if the recruiters focused solely on their minimum requirement first.

TTCN	CostN	TTCB	CostB
4.45	1.20	4.24	1.18

Table 12 Simulation Results

The time it takes 4,200 recruiters to produce 90,000 recruits under the quota system can be compared to this time under the BIRM. If the recruiters produced at the current historical average of about 1.29 recruits per month, then it would take the 4,200 recruiters about 16.60 months to achieve the 90,000 recruit goal. The Recruiting Command is hiring 750 more recruiters to reduce this 4.6 month deficit to zero. However, even with the extra recruiters, the efficiency level of the recruiters must increase

because 4,950 recruiters would have to average at least 1.51 recruits per month to reach 90,000 recruits in 12 months.[5] The conclusion drawn from this analysis is that the two programs would achieve the recruiting goal in about the same amount of time.

2. CostN Costs Analysis

The simulation compiled the cost for the BIRM and calculated the cost of the additional recruiters under the quota system. All recruiters receive an allowance for being on recruiting duty. This supplementary pay was assumed to be the only relevant cost to USAREC for hiring more recruiters. The current range of the supplementary pay is between \$165 and \$275. If the median cost for the supplementary pay amount was used, then the total cost for the 750 additional recruiters would be almost 1.98 million dollars. The best case cost is when the recruiters receive \$165 per month, for a total cost of 1.5 million dollars.

The simulation estimated the cost of the BIRM by generating prediction and production levels for the recruiters, and these in turn determined the bonus amount. The recruiter's bonuses were aggregated until the simulation showed that the recruiters produced 39,600 recruits. The total cost is also shown in Table 11. The average cost was 1.28 million dollars for the normally distributed production function.

The absolute "worst" case cost of the BIRM can be estimated by assuming that all recruiters predict and produce two recruits per month. At this prediction and production level, the marginal return for a recruit is highest, equal to \$50. The estimated cost would be:

$$4200 \text{ recruiters} \times 12 \text{ months} \times \frac{\$50}{\text{recruiter-month}} = 2.52 \text{ million dollars} \quad (9)$$

[5] The most recent production data from USAREC shows that the recruiters have increased their production. Appendix E shows what the recruiters have produced for the first ten months of FY 95.

The calculated worst case cost under the quota system is:

$$50\ recruiters \mathbf{x}\ 12\ months\ \mathbf{x}\ \frac{\$275}{recruiter\text{-}month} = 2.48\ million\ dollars \qquad (10)$$

This analysis shows that the two worst case costs are almost the same, but the expected cost under the BIRM was significantly less than the median or best case cost under the quota system.

B. BETA DISTRIBUTED PRODUCTION

1. TTCB

The same approach that was taken to analyze TTCN and CostN was taken to analyze TTCB and CostB. From Table 12, the average TTCB was 4.24 months, just a little less than the normally distributed production. Similar analysis that applied to the normally distributed production function will follow for the beta distributed production function. The total time to complete the 90,000 recruit mission would take 16.24 months if the recruiters concentrated on producing one recruit per month for the first 12 months and then the recruits under the BIRM. The time expectancy under the quota system would again be 16.60 months. The conclusion drawn from this analysis is the two programs should achieve the goal in about the same amount of time.

2. CostB Cost Analysis

The analysis of the cost (CostB) using the beta distribution production function is identical to the analysis of the cost under the normally distributed production. The cost under the beta distributed production function averaged 1.18 million dollars. This cost is less than the cost for the normally distributed production functions and the estimated costs under the quota system. If our intuition is correct on the production distribution, then the best cost is achieved if the beta distribution models the production distribution.

C. SENSITIVITY ANALYSIS OF THE MODEL

The data collection was designed so that sensitivity analysis of the relevant factors of the utility and cost functions could be conducted. The simulation could be characterized as a 2^4 factorial design, and MINITAB® Statistical software was used to obtain the results in Appendix D.

1. Factors and Levels

The factors tested in this experiment were α and β from the cost function, and B and θ for the utility function. Third order and higher interactions between the factors were assumed not to be significant, so the experiment determined the main effects and second order interaction effects of the four factors.

The levels for each of the factors are shown in Table 13. The levels were chosen so that they could provide as much information about their effects as possible. Realistic levels for each variable were also chosen. For β, the two levels were chosen so that one cost function was nearly linear (β= 1.1) and the other cost function increased exponentially (β = 2.0). The other factors were chosen similarly.

2. TTC Design of Experiment and Results

The effects of the cost and utility parameters were estimated with the data in Appendix C. Complete tables showing the main effects and interaction effects are shown in Appendix D for TTCN, TTCB, CostN, and CostB. Table 13 summarizes the results of the effects for the four variables. α, β, B, and the interaction between α and B are the common significant effects of the four outputs. (Significance level = .10)

Factor	Low	High
α	.10	.20
β	1.1	2.0
B	3	8
θ	3	8

Table 13 Factors and Levels

The most dominating factor for TTCN and TTCB was β. It had a 60% greater effect than α. This implies that the cost function with its two parameters is the critical driver for the time it takes the recruiters to achieve their mission. If the recruiters expect to pay a high cost for recruiting p recruits, then the time will go up significantly. Surprisingly, the interaction between α and β is not a significant effect, but separately, they exert the most control over TTC. As far as the utility function, B and its interaction with α are the most significant parameters. B, however, still has only half the effect of β on the TTC. From this analysis, the proper identification of the cost function of the recruiter is one of the most important elements of the simulation.

3. Cost Design of Experiment and Results

For the cost analysis, α , β and B have almost similar effects on the cost, regardless of how the recruiter's production is modeled. However, in CostN, the most significant effects are the interaction effects of α and β, and the interaction effects of β and B. For CostB, the four significant effects have almost the same magnitude, but the interaction effects of α and B are negative. The conclusion drawn again is the recruiters cost function plays a large role in determining the cost of the BIRM, so care should be taken to correctly model it.

	TTCN	TTCB	CostN	CostB
Alpha (α)	X	X	X	X
Beta (β)	X	X	X	X
B	X	X	X	X
Alpha * B	X	X	X	X
Beta * B		X	X	
Alpha * Beta			X	

Table 14 Significant Effects of Each Variable

D. COMPARISON BETWEEN THE TWO PRODUCTION FUNCTIONS

1. TTC

The data was tested to find out if the production probability distributions (normal versus beta) produced significantly different results. The raw data showed that the TTCN was 0.21 higher than TTCB. The following hypothesis was tested:

$$\begin{aligned} H_0 &: \mu_{TTCN} = \mu_{TTCB} \\ H_1 &: \mu_{TTCN} > \mu_{TTCB} \end{aligned} \tag{11}$$

Equation 11 was used to determine the test statistic. The test parameter was $z_{.05} = 1.6445$. For the TTCN and TTCB data, $Z = .74516$.

The null hypothesis is not rejected since $Z < z_{.05}$, and the conclusion drawn is that the normally distributed production function does not produce higher TTC amounts over the beta distributed production function. It appears that the recruiter's production matters only at the individual level. Once the production is aggregated, the differences between the two production functions is insignificant.

$$Z = \frac{(\overline{TTCN} - \overline{TTCB}) - D_0}{\sqrt{\frac{\sigma^2_{TTCN}}{16} + \frac{\sigma^2_{TTCB}}{16}}} \tag{12}$$

2. Cost

Differences for the cost data was tested. Our hypothesis was:

$$\begin{aligned} H_0 &: \mu_{CostN} = \mu_{CostB} \\ H_1 &: \mu_{CostN} > \mu_{CostB} \end{aligned} \tag{13}$$

Equation (11) with the cost data was substituted in, and Z = .56216 was obtained. Again, the null hypothesis is not rejected since $Z < z_{.05}$, and the conclusion is that the production function does not significantly affect the cost.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The United States Army Recruiting Command (USAREC) must increase their efficiency as they go into the 21st century. The current quota-based incentive system may not be the most efficient way to motivate recruiters to produce at their highest levels.

The BIRM is an incentive structure that allows the recruiters to provide input on how much their local area can produce. The recruiters provide this information to USAREC by forecasting how many they can produce for each month. The recruiters are paid a bonus for every recruit that they produce over one.

The bonus table is a critical element of the BIRM. If the bonus payments are too low, then the recruiters will not be motivated to overproduce, and if the bonus payments are too high, then USAREC will have more recruits than it needs and would have paid more than was necessary.

Background information for developing the bonus table was discussed. It showed how the recruiter's forecast and production is tied into the bonus payment, so that production that is either greater or smaller than the forecast is penalized an appropriate amount. Additionally, several factors are discussed that should be considered when setting the bonus levels.

The key to the BIRM is to understand how and what influences a recruiter's decision to forecast a certain production level. Two different methods were used to model the recruiter's decision problem and each provided unique insights. The first method used decision theory constructs. This process revealed that if a recruiter used expected values to make his decision, then he would forecast the level his market would produce.

The utility based model dealt with the utility the recruiters derived from the bonus payment. USAREC controls the levels of the bonus payments, and the bonus payment should control the levels that the recruiter produces. A well-known utility function was used to model the recruiter's utility function for money. With this utility function, a cost function that described the cost to the recruiter for recruiting p recruits was generated. This cost was not an external cost, but a perceived cost to the recruiter.

When the costs of the quota based system were compared with the simulation generated BIRM costs, the costs under the BIRM were found to be significantly lower than the costs under the quota system. Even the worst case cost of the BIRM was better than the expected cost under the quota system.

Finally, the production distribution of the individual recruiter does not significantly affect the time to completion and costs of the BIRM. For the utility and cost functions, the parameters α, β, and B were significant to the TTC variable and cost variable, along with some of their interactions. Future empirical work should attempt to determine the exact nature of these distributions, especially the recruiter's cost function.

Overall, the BIRM should outperform the quota-based system, with a minimum of extra work. Under the quota-based system, each recruiter would have to produce 1.5 recruits per month, or six recruits in a four month period. Under the BIRM, the recruiters would have to produce 1.75 recruits per month, or seven recruits in a four month period. The recruiters would have to produce only one more recruit over the four months, and would receive a bonus for the production of three of the seven recruits. The simulation estimated the cost of paying this recruiter the bonus would be less than hiring more recruiters.

B. RECOMMENDATIONS

USAREC should initiate a pilot plan to test the BIRM with recruiters at a battalion. A battalion is recommended for the smallest test group because a battalion can encompass

different recruiting environments, so that data on the diverse situations in which recruiters work could be collected. The recruiting command should also focus their attention on determining the exact nature of the recruiter's utility and cost functions.

APPENDIX A TURBO PASCAL® RANDOM NUMBER GENERATOR

In order for the simulation to be credible, the random number generator used in the simulation must appear "random". The Chi Square test was used to check the random number generator. The Turbo Pascal® built-in generator was checked since it was the programming language used in the simulation. The Turbo Pascal® random number generator consistently passed the Chi-square test.

32,768 ($n=2^{15}$) integer random variates wre generated between the values of 0 and 4096. Each integer between these two values was made a "bin." Each random number that was generated was placed into its corresponding bin. The Chi Square test was used to check for uniformity. Of 100 runs using this test, 89% of the time the null hypothesis would not have been rejected, so the conclusion drawn is that the variates were distributed uniformly over the interval. The results of this test are included at the end of this appendix.

RANDOM NUMBER TEST RESULTS

Test	Chi Stat	Chi Test Stat	Difference	Test	Stat	Test Stat	Chi Difference	Chi	
1	17.14	27.18		10.04		51	23.34	27.18	3.84
2	11.24	27.18		15.94		52	16.14	27.18	11.05
3	25.23	27.18		1.96		53	45.04	27.18	-17.86
4	19.37	27.18		7.82		54	30.11	27.18	-2.93
5	13.06	27.18		14.12		55	15.40	27.18	11.78
6	25.10	27.18		2.09		56	11.04	27.18	16.14
7	17.71	27.18		9.47		57	23.91	27.18	3.27
8	18.75	27.18		8.43		58	22.00	27.18	5.19
9	13.48	27.18		13.70		59	19.94	27.18	7.25
10	20.70	27.18		6.48		60	11.16	27.18	16.03
11	19.29	27.18		7.89		61	27.87	27.18	-0.69
12	14.51	27.18		12.67		62	8.42	27.18	18.77
13	25.12	27.18		2.06		63	18.24	27.18	8.94
14	16.25	27.18		10.94		64	15.70	27.18	11.49
15	26.78	27.18		0.40		65	12.59	27.18	14.59
16	13.97	27.18		13.22		66	20.35	27.18	6.84
17	21.33	27.18		5.85		67	21.10	27.18	6.09
18	21.55	27.18		5.63		68	17.18	27.18	10.00
19	19.29	27.18		7.89		69	14.94	27.18	12.25
20	30.24	27.18		-3.06		70	30.16	27.18	-2.98
21	26.03	27.18		1.15		71	34.16	27.18	-6.97
22	22.01	27.18		5.17		72	11.50	27.18	15.68
23	13.91	27.18		13.28		73	17.09	27.18	10.09
24	33.48	27.18		-6.30		74	16.82	27.18	10.37
25	27.42	27.18		-0.23		75	18.68	27.18	8.50
26	20.04	27.18		7.15		76	25.52	27.18	1.67
27	29.04	27.18		-1.86		77	7.00	27.18	20.18
28	19.08	27.18		8.11		78	24.68	27.18	2.50
29	19.56	27.18		7.62		79	21.53	27.18	5.65
30	16.02	27.18		11.17		80	9.34	27.18	17.85
31	22.17	27.18		5.02		81	9.63	27.18	17.55
32	10.04	27.18		17.14		82	18.62	27.18	8.56
33	20.73	27.18		6.46		83	34.94	27.18	-7.76
34	19.01	27.18		8.17		84	20.08	27.18	7.10
35	15.16	27.18		12.03		85	17.80	27.18	9.38
36	19.86	27.18		7.32		86	20.51	27.18	6.67
37	24.00	27.18		3.18		87	18.99	27.18	8.20
38	18.42	27.18		8.76		88	15.17	27.18	12.02
39	23.20	27.18		3.98		89	13.73	27.18	13.45
40	20.47	27.18		6.71		90	16.99	27.18	10.19
41	16.84	27.18		10.34		91	15.13	27.18	12.06
42	14.19	27.18		13.00		92	17.98	27.18	9.20
43	19.36	27.18		7.82		93	26.03	27.18	1.15
44	22.04	27.18		5.14		94	20.25	27.18	6.93
45	16.66	27.18		10.52		95	10.93	27.18	16.26
46	15.22	27.18		11.96		96	18.04	27.18	9.14
47	7.61	27.18		19.57		97	25.31	27.18	1.87
48	17.51	27.18		9.68		98	13.34	27.18	13.84
49	25.39	27.18		1.79		99	12.17	27.18	15.01
50	28.57	27.18		-1.38		100	12.41	27.18	14.77

Number of Gos = 89
Number of No Gos = 11

APPENDIX B PASCAL SIMULATION SOURCE CODE

```
Program Engine;

uses CRT,Rand1,Stats,DOS,Graph;

const  Recruitforcesize      =     300;
       maxtablesize          =     6;
       Million               =     1000000;
       gd      :Integer      =     VGA;

type RecruiterType= record
       RecruitersUtility     : Array [1..maxtablesize] Of Real;
       RecruitersCost        : Array [1..maxtablesize] Of Real;
       Prediction            : Array [1..12] Of Integer;
       Production            : Array [1..12] Of Integer;
       BonusPayment          : Array [1..12] Of Real;
      end;
  StationType = array[1..RecruitForcesize] of RecruiterType;

type ForceType = record
      TotMonthPred           : Array [1..12] of LongInt;
      TotMonthProd           : Array [1..12] of LongInt;
      TotMonthBonus          : Array [1..12] of Double;
      end;

type AggregateType =record
      DataPred          : Array [1..12] of LongInt;
      DataProd          : Array [1..12] of LongInt;
      DataBonus         : Array [1..12] of Real;
      end;

var Recruiter               : StationType;
   RecruiterForce           : array [1..14] of ForceType;
   Data                     : AggregateType;
   YTDPred                  : Longint;
   YTDProd                  : Longint;
   YTDBonus                 : real;
   BonusTotal               : real;
   YTDBonusAvg              : real;
   cutoff                   : LongInt;
   Cutoffpoint              : Integer;
```

```
CutoffpointAvg1          : Real;
CutoffpointAvg2          : Real;
CutOffPtTotal            : Integer;
Cycle                    : Integer;
SampVar                  : Real;
StopTest                 : Real;
BonusTable               : array[1..6, 1..6] of real;
Flag                     : Boolean;
outfile                  : text;
outfile2                 : text;
h1, min1, sec1, hund1    : word;
h2, min2, sec2, hund2    : word;
h3, min3, sec3, hund3    : word;
RunTime,TotTime          : real;
Alphamean                : real;
Betamean                 : real;
Bmean                    : real;
Thetamean                : real;
Alphastdev               : real;
Betastdev                : real;
Bstdev                   : real;
Thetastdev               : real;
TPM                      : integer;
gm                       : integer;
```

```
{*********************************************************************
*********************************************************************
****              Procedures/Functions                  ****
*********************************************************************
*********************************************************************

Procedure ProgramInitialization;
  Begin
    If  ODD(TPM)
      then begin Alphamean:= 0.10; end
      else begin Alphamean:= 0.20;
    end;
    If TPM=(1 or 2 or 5 or 6 or 9 or 10 or 13 or 14)
       then begin Betamean:=  1.1; end
       else begin Betamean:=  2.0;
    end;
    If (TPM <= 4) or ((TPM >=9) and (TPM <= 12 ))
        then begin Bmean :=    3; end
        else begin Bmean :=    8;
    end;
    If (TPM < 9)
        then begin Thetamean:=    3; end
        else begin Thetamean:=    8;
    end;
    Alphastdev := 0.05;
    Betastdev  := 0.25;
    Bstdev     := 1.0;
    Thetastdev := 1.0;
    if (TPM = 1)   then  Assign(outfile,'C:\nps\thesis\Case1c.pas');
    if (TPM = 2)   then  Assign(outfile,'C:\nps\thesis\Case2c.pas');
    if (TPM = 3)   then  Assign(outfile,'C:\nps\thesis\Case3c.pas');
    if (TPM = 4)   then  Assign(outfile,'C:\nps\thesis\Case4c.pas');
    If (TPM = 5)   then  Assign(outfile,'C:\nps\thesis\Case5c.pas');
    if (TPM = 6)   then  Assign(outfile,'C:\nps\thesis\Case6c.pas');
    if (TPM = 7)   then  Assign(outfile,'C:\nps\thesis\Case7c.pas');
    if (TPM = 8)   then  Assign(outfile,'C:\nps\thesis\Case8c.pas');
    If (TPM = 9)   then  Assign(outfile,'C:\nps\thesis\Case9c.pas');
    if (TPM = 10)  then  Assign(outfile,'C:\nps\thesis\Case10c.pas');
    if (TPM = 11)  then  Assign(outfile,'C:\nps\thesis\Case11c.pas');
    if (TPM = 12)  then  Assign(outfile,'C:\nps\thesis\Case12c.pas');
    If (TPM = 13)  then  Assign(outfile,'C:\nps\thesis\Case13c.pas');
    if (TPM = 14)  then  Assign(outfile,'C:\nps\thesis\Case14c.pas');
    if (TPM = 15)  then  Assign(outfile,'C:\nps\thesis\Case15c.pas');
    if (TPM = 16)  then  Assign(outfile,'C:\nps\thesis\Case16c.pas');
    rewrite(outfile);
```

```
    GetTime(h1, min1, sec1, hund1);
    Cutoff:=39600;
    CutOffPointAvg1:=0.0;
    CutOffPointAvg2:=0.0;
    CutOffPtTotal:=0;
    BonusTotal:=0;
    YTDBonus:=0;
    SampVar:=0.0;
    Cycle:=0;

    writeln(outfile);
    writeln(outfile,'Alpha := Normal(',Alphamean:3:2, ',',alphastdev:3:2,')');
    writeln(outfile,'Beta  := Normal(',Betamean:3:2,',',Betastdev:3:2,')');
    writeln(outfile,'B     := Normal(',Bmean:3:2,',',Bstdev:3:2,')');
    writeln(outfile,'Theta := Normal(',Thetamean:3:2,',',Thetastdev:3:2,')');
    writeln(outfile);

  end;

Procedure BonusTableDev;
  var   k,p,t:integer;
      BaseTable : array[1..10, 1..10] of real;
      Amount1:real;
      response : char;
  Begin
    Randomize;
    {Calculate the Base Table }
    For k := 1 to maxtablesize do begin
      For  p := 1 to maxtablesize do begin
        if p >= k then begin
          BaseTable[k,p]:= (k-p)/p;
        end
        else begin
          BaseTable[k,p] :=(k-p)/k;
        end
      end;
    end;
```

```
{******************DEVELOP THE BONUS TABLE**********************}

   for P:=1 to maxtablesize do begin
     BonusTable[p,p]:=50 +(p-1)*25;
   end;

{Base Payment Vector (BPV)}

   {BonusTable[1,1]:=50;
   BonusTable[2,2]:=75;
   BonusTable[3,3]:=100;
   BonusTable[4,4]:=125;
   BonusTable[5,5]:=150;
   BonusTable[6,6]:=175;}
{Calculate the rest of the table}
   for p:=1 to maxtablesize do begin
     for k:=1 to maxtablesize do begin
       if k > p then begin
         t:=k;
         Amount1:=1;
         Repeat
           Amount1 :=Amount1*BaseTable[t,p];
           dec(t);
         until t =p;

         BonusTable[k,p]:=BonusTable[k-1,p]+(Amount1)*(BonusTable[k,k]-
               BonusTable[k-1,k-1]);
       end;
       if k < p then begin
         t:=p;
         Amount1:=1;
         Repeat
           Amount1 :=Amount1*BaseTable[k,t];
           dec(t);
         until t =k;

         BonusTable[k,p]:=BonusTable[k,p-1]-(1-Amount1)*
                  (BonusTable[p,p]-BonusTable[p-1,p-1]);
         If BonusTable[k,p] < 0 then BonusTable[k,p]:=0;
       end;
     end;
   end;
end;
```

```
Procedure Initialize;  {Initializes the recruiter's individual
                characteristics}
  var i,j,a:integer;

  Begin
    For i:=1 to RecruitForcesize do begin
      For j:=1 to 12 do begin
        Recruiter[i].Prediction[j]:=0;
        Recruiter[i].Production[j]:=0;
        Recruiter[i].BonusPayment[j]:=0;
      end;
    end;
    For a:=1 to 12 do begin
        Data.DataPred[a]:=0;
        Data.DataProd[a]:=0;
        Data.DataBonus[a]:=0;
    end;
  end;

Procedure Utility;  {Create the recruiter's Utility and Cost Functions}

   var i,x,d:integer;
     alpha, Beta,Theta,B:real;
     DecisionVar:real;
   Begin

     repeat
       Alpha:=Normal(Alphamean,0.03);
     until Alpha > 0;
     repeat
       Beta:=Normal(Betamean,2);
     until Beta > 0;
     repeat
       B:=Normal(Bmean,2);
     until (B > 1);
     repeat
       Theta:=Normal(Thetamean,0.5);
     until Theta > 0;

     For i:=1 to RecruitForcesize do begin
       For x:=1 to maxtablesize do begin
         Recruiter[i].RecruitersUtility[x]:=
                 (ln (1+( (B-1)*(BonusTable[x,x]) /theta))) / (ln(B));
         Recruiter[i].RecruitersCost[x]:=
                 alpha*(Power(x,Beta));
```

```
      end;
    end;
  end; {Utility}

Function GetPrediction(RecruiterID:Integer):Integer;
  var UtilDiff,UtilTest: real;
     Input,Prediction,i:integer;
  Begin
    Prediction:=0;
    i:=1;
    UtilTest:=0;
    repeat
      UtilDiff:=Recruiter[RecruiterID].RecruitersUtility[i]-
             Recruiter[RecruiterID].RecruitersCost[i];
      If (UtilDiff > UtilTest) then begin
        UtilTest:=UtilDiff;
        Inc(Prediction);
        Inc(i);
      end
      else begin
        i:=6;
      end;
    until (i=6) ;
    If Prediction <= 0 then begin GetPrediction:= 1;end
    else if Prediction > 5 then begin GetPrediction:=5;end
    else begin   GetPrediction := Prediction;end;

  end;  {GetPrediction}

Function GetProduction(RecruiterID,mth:Integer):Integer;
  var Test,Input: real;
     Production:Integer;
  Begin
    Test:=Random;
    {Test:=Normal(Recruiter[RecruiterID].Prediction[Mth],2);
    Production:=Round(test);}
    Production:=Beta(Recruiter[RecruiterID].Prediction[Mth]);
    if Production > 5 then begin GetProduction:=5;end
    else if Production <= 0 then begin GetProduction:=1;end
    else begin GetProduction:=Production;end;
  end;
```

```
Function GetBonusPayment(RecruiterID,mth:Integer):Real;
  var Payment:real;
  Begin
    if (Recruiter[RecruiterID].Production[Mth] or
                      Recruiter[RecruiterID].Prediction[Mth])= 0
      then  begin Payment := 0;end
    else if (Recruiter[RecruiterID].Production[Mth] or
                      Recruiter[RecruiterID].Prediction[Mth])> 5
      then  begin Payment :=
              BonusTable[Recruiter[RecruiterID].Production[5],
                      Recruiter[RecruiterID].Prediction[5]];end
    else begin
      Payment:=BonusTable[Recruiter[RecruiterID].Production[Mth],
                      Recruiter[RecruiterID].Prediction[Mth]];
    end;
    if (Payment < 0) then begin
     {writeln(outfile,'Uh-oh, Progam ALERT!!!');}
     GetBonusPayment:=0;
    end
    else begin
      GetBonusPayment:=Payment;
    end;
  end;

Procedure AggregatePrediction(Que:integer) ;
     var m,t:integer;
        TotPrediction,TotProduction:LongInt;
        TotBonus :Real;
  Begin
    for m:=1 to 12 do begin
      TotPrediction:=0;
      TotProduction:=0;
      TotBonus:=0;
      for t:=1 to RecruitForcesize do begin
        TotPrediction:= TotPrediction +
              (Recruiter[t].Prediction[m]);
        TotProduction:= TotProduction +
              (Recruiter[t].Production[m]);
        TotBonus:= TotBonus +
              (Recruiter[t].BonusPayment[m]);
      end;

      {Keep a running count for each batch of 300 recruiters}
      RecruiterForce[que].TotMonthPred[m]:=TotPrediction;
      RecruiterForce[que].TotMonthProd[m]:=TotProduction;
```

```
      RecruiterForce[que].TotMonthBonus[m]:=TotBonus;
      end;
    end;

Procedure MonthStats;
    var f,h:integer;

    Begin
      for f := 1 to 12 do begin
        For h:=1 to 14  do begin
          Data.DataPred[f]:=Data.DataPred[f]+
            RecruiterForce[h].TotMonthPred[f];
          Data.DataProd[f]:=Data.DataProd[f]+
            RecruiterForce[h].TotmonthProd[f];
          Data.DataBonus[f]:= Data.DataBonus[f] +
            (RecruiterForce[h].TotmonthBonus[f])/million;
        end;
      end;
    end;

Procedure YTDStats;
    var d       :integer ;

    Begin
      YTDPred:=0;
      YTDProd:=0;
      YTDBonus:=0;
      for d:=1 to 12 do begin
        if flag = false then begin
          YTDPred:=YTDPred+Data.DataPred[d];
          YTDProd:=YTDProd+Data.DataProd[d];
          YTDBonus:=YTDBonus+Data.DataBonus[d];
          if (YTDProd > Cutoff) and (Flag=False) then begin
            Flag:=True;
            CutoffPoint:=d;
            d:=12;
          end;
        end;
      end;
    end;

Procedure Simulate;

  var q,month,j:integer;
```

```
Begin
  For q:=1 to 14 do begin  {We are simulating 300 recruiters x 14 =4200}
    Initialize;
    Utility;
    For Month:=1 to 12 do begin
      RecruiterForce[q].TotMonthPred[month]:=0;
      RecruiterForce[q].TotMonthProd[month]:=0;
      RecruiterForce[q].TotMonthBonus[month]:=0;
      For j:=1 to Recruitforcesize do begin
        Recruiter[j].Prediction[Month]:=GetPrediction(j);
        Recruiter[j].Production[Month]:=GetProduction(j,month);
        Recruiter[j].BonusPayment[Month]:=GetBonusPayment(j,month);
      end;{For}
    end;{For}
    AggregatePrediction(q);
  end;
end;

Procedure CutoffDetermination;

Begin
  CutOffPtTotal:=CutOffPtTotal + CutoffPoint;
  CutOffPointAvg1:=CutOffPtTotal/Cycle;
  BonusTotal:=BonusTotal+YTDBonus;
  YTDBonusAvg:=BonusTotal/cycle;
  writeln(outfile,'Cycle ',Cycle:3);
  writeln(outfile,'CutOff Month:     ', CutOffPoint:2,
       '  Average   = ',CutOffPointAvg1:4:2);

  if Cycle > 1 then begin
    SampVar:=((Cycle-1)*SampVar/Cycle)+Sqr(CutOffPointAvg2)-
         ((Cycle)*Sqr(CutOffPointAvg1)/(Cycle-1))+
         (Sqr(CutOffPoint))/(Cycle-1);
    write(outfile,'Samp Variance:  ',SampVar:4:2);
  end;
  CutOffPointAvg2:=CutoffPointAvg1;
  if SampVar > 0 then begin
    Stoptest:=(1.96*sqrt(SampVar/Cycle))/CutoffPointAvg2;
    writeln(outfile,'   Stop Test = ',StopTest:4:2);
  end;
  {GetTime(h3, min3, sec3, hund3);
  writeln(outfile, 'Current Time   ',h3,':', min3,':', sec3,':', hund3);}
  writeln(outfile, 'Bonus payment:  ',YTDBonus:4:2,
              '  Average   = ',YTDBonusAvg:4:2);
  writeln(outfile);
```

```
end;

Procedure GetRunTime;

Begin
  GetTime(h2, min2, sec2, hund2);
  writeln(outfile);
  writeln(outfile,'******************************************************');
  writeln(outfile, 'Start Time    ',h1,':', min1,':', sec1,':', hund1);
  writeln(outfile, 'Finish Time   ',h2,':', min2,':', sec2,':', hund2);

  if h1 > 12 then h1:=h1-12;
  if h2 > 12 then h2:=h2-12;

  RunTime:=    ( (h2*3600)+(min2*60)+(sec2+(hund2/100)) )-
            ( (h1*3600)+(min1*60)+(sec1+(hund1/100)) ) ;

  writeln(outfile,'Running Time is ', Runtime:8:2,' seconds');
  writeln(outfile,'Running Time is ',(RunTime/60):8:3,' minutes');
  writeln(outfile);

end;
```

```
{**********************************************************************
***                    Main Program                    ***
**********************************************************************}


Begin
  Randomize;
  Initgraph(gd,gm, 'c:\or-pgms\tp\bgi');
  maxX:= GetMaxX;
  maxY:= GetMaxY;
  For TPM :=9 to 16 do begin
    ProgramInitialization;
    BonusTableDev;
    repeat
      repeat
       until (pot1 and pot2) > 0 ;
      ClearDevice;
      Inc(Cycle);
      Flag:=False;
      Simulate;
      MonthStats;
      YTDStats;
      CutoffDetermination;
    until ((StopTest < 0.025) and (Cycle > 10)) or (Cycle=150) ;

    GetRunTime;
    close(outfile);
  end;
  Sound(150);
  Delay(400);
  nosound;
  Closegraph;
End.
```

APPENDIX C SIMULATION RAW DATA

Table 15 summarizes the raw data from the simulation. TTCN is the time to completion of the recruiting mission when the recruiter's production is modeled as normally distributed. CostN is the estimated cost of the BIRM to recruit 39,600 civilians. TTCB and CostB are the same as TTCN and CostN, but with the recruiter's production distribution modeled as beta distributed.

Run	TTCN	CostN	TTCB	CostB
1	3.00	1.28	3.00	.96
2	3.49	1.09	3.89	1.13
2	4.34	1.06	4.00	1.05
4	5.37	1.27	4.94	1.33
5	3.43	1.08	3.89	1.23
6	4.80	1.21	4.36	1.19
7	5.13	1.22	4.79	1.27
8	6.00	1.45	5.00	1.31
9	3.00	1.26	3.00	.98
10	3.54	1.09	3.93	1.23
11	4.33	1.00	4.04	1.08
12	5.36	1.26	4.95	1.30
13	3.49	1.10	3.95	1.14
14	4.84	1.23	4.29	1.16
15	5.06	1.20	4.80	1.28
16	6.00	1.45	5.00	1.31
AVG	4.45	1.20	4.24	1.18

Table 15 Simulation Results

APPENDIX D EXPERIMENTAL DESIGN RESULTS

A. ESTIMATED EFFECTS AND COEFFICIENTS FOR TTCN

1. Estimated Effects and Coefficients for TTCN-Full Model.

Term	Effect	Coef	StdCoef	t-value	P
Constant		4.44875	0.05445	81.70	0.000
Alpha	0.95250	0.47625	0.05445	8.75	0.000
Beta	1.50000	0.75000	0.05445	13.77	0.000
B	0.79000	0.39500	0.05445	7.25	0.001
Theta	0.00750	0.00375	0.05445	0.07	0.948
Alpha*Beta	0.01500	0.00750	0.05445	0.14	0.896
Alpha*B	0.18000	0.09000	0.05445	1.65	0.159
Alpha*Theta	0.01250	0.00625	0.05445	0.11	0.913
Beta*B	-0.09250	-0.04625	0.05445	-0.85	0.434
Beta*Theta	-0.03000	-0.01500	0.05445	-0.28	0.794
B*Theta	-0.00000	-0.00000	0.05445	-0.00	1.000

Table 16 Estimated Effects of TTCN

2. Estimated Effects and Coefficients for TTCN- Reduced Model.

Term	Effect	Coef	Std Coef	t-value	P
Constant		4.44875	0.03965	112.19	0.000
Alpha	0.95250	0.47625	0.03965	12.01	0.000
Beta	1.50000	0.75000	0.03965	18.91	0.000
B	0.79000	0.39500	0.03965	9.96	0.000
Alpha*B	0.18000	0.09000	0.03965	2.27	0.044

Table 17 Estimated Effects of TTCN (Reduced Model)

B. ESTIMATED EFFECTS AND COEFFICIENTS FOR TTCB

1. Estimated Effects and Coefficients for TTCB - Full Model

Term	Effect	Coef	StdCoef	t-value	P
Constant		4.2394	0.01387	305.74	0.000
Alpha	0.6112	0.3056	0.01387	22.04	0.000
Beta	0.9012	0.4506	0.01387	32.50	0.000
B	0.5413	0.2706	0.01387	19.52	0.000
Theta	0.0112	0.0056	0.01387	0.41	0.702
Alpha*Beta	-0.0463	-0.0231	0.01387	-1.67	0.156
Alpha*B	-0.3063	-0.1531	0.01387	-11.04	0.000
Alpha*Theta	-0.0163	-0.0081	0.01387	-0.59	0.583
Beta*B	-0.1262	-0.0631	0.01387	-4.55	0.006
Beta*Theta	0.0038	0.0019	0.01387	0.14	0.898
B*Theta	-0.0112	-0.0056	0.01387	-0.41	0.702

Table 18 Estimated Effects of TTCB

2. Estimated Effects and Coefficients for TTCB - Reduced Model

Term	Effect	Coef	StdCoef	t-value	P
Constant		4.2394	0.01276	332.16	0.000
Alpha	0.6112	0.3056	0.01276	23.95	0.000
Beta	0.9012	0.4506	0.01276	35.31	0.000
B	0.5413	0.2706	0.01276	21.20	0.000
Alpha*B	-0.3063	-0.1531	0.01276	-12.00	0.000
Beta*B	-0.1262	-0.0631	0.01276	-4.95	0.000

Table 19 Estimated Effects of TTCB (Reduced Model)

3. Unusual Observations for TTCB

Obs.	TTCB	Fit	Stdev.Fit	Residual	St.Resid
6	4.36000	4.27500	0.03126	0.08500	2.11R

Table 20 Unusual Observations of TTCB

C. ESTIMATED EFFECTS AND COEFFICIENTS FOR COSTN

1. Estimated Effects and Coefficients for CostN - Full Model

Term	Effect	Coef	Std Coef	t-value	P
Constant		1.20313	0.01717	70.08	0.000
Alpha	0.10625	0.05313	0.01717	3.09	0.027
Beta	0.07125	0.03562	0.01717	2.07	0.093
B	0.07875	0.03938	0.01717	2.29	0.070
Theta	-0.00875	-0.00437	0.01717	-0.25	0.809
Alp*Beta	0.13125	0.06562	0.01717	3.82	0.012
Alpha*B	0.07875	0.03937	0.01717	2.29	0.070
Alpha*Theta	0.01125	0.00562	0.01717	0.33	0.756
Beta*B	0.10375	0.05188	0.01717	3.02	0.029
Beta*Theta	-0.01375	-0.00687	0.01717	-0.40	0.705
B*Theta	0.01375	0.00687	0.01717	0.40	0.705

Table 21 Estimated Effects of CostN

2. Estimated Effects and Coefficients for CostN- Reduced Model

Term	Effect	Coef	Std Coef	t-value	P
Constant		1.20313	0.01341	89.70	0.000
Alpha	0.10625	0.05313	0.01341	3.96	0.003
Beta	0.07125	0.03562	0.01341	2.66	0.026
B	0.07875	0.03938	0.01341	2.94	0.017
Alpha*Beta	0.13125	0.06562	0.01341	4.89	0.000
Alpha*B	0.07875	0.03937	0.01341	2.94	0.017
Beta*B	0.10375	0.05188	0.01341	3.87	0.004

Table 22 Estimated Effects of CostN (Reduced Model)

D. ESTIMATED EFFECTS AND COEFFICIENTS FOR COSTB

1. Estimated Effects and Coefficients for CostB - Full Model

Term	Effect	Coef	StdCoef	t-value	P
Constant		1.18438	0.009375	126.33	0.000
Alpha	0.12125	0.06062	0.009375	6.47	0.001
Beta	0.11375	0.05687	0.009375	6.07	0.002
B	0.10375	0.05187	0.009375	5.53	0.003
Theta	0.00125	0.00062	0.009375	0.07	0.949
Alp*Beta	0.02125	0.01062	0.009375	1.13	0.308
Alpha*B	-0.10875	-0.05438	0.009375	-5.80	0.002
Alpha*Theta	0.00875	0.00437	0.009375	0.47	0.660
Beta*B	-0.00125	-0.00063	0.009375	-0.07	0.949
Beta*Theta	0.00125	0.00063	0.009375	0.07	0.949
B*Theta	-0.02875	-0.01438	0.009375	-1.53	0.186

Table 23 Estimated Effects of CostB

2. Estimated Effects and Coefficients for CostB - Reduced Model

Term	Effect	Coef	Std Coef	t-value	P
Constant		1.18438	0.008417	140.71	0.000
Alpha	0.12125	0.06062	0.008417	7.20	0.000
Beta	0.11375	0.05687	0.008417	6.76	0.000
B	0.10375	0.05187	0.008417	6.16	0.000
Alpha*B	-0.10875	-0.05438	0.008417	-6.46	0.000

Table 24 Estimated Effects of CostN (Reduced Model)

3. Unusual Observations for CostB

Obs.	CostB	Fit	Stdev.Fit	Residual	St.Resid
2	1.13000	1.19063	0.01882	-0.06063	-2.17R
5	1.23000	1.17313	0.01882	0.05687	2.04R

Table 25 Unusual Observations of TTCB

APPENDIX E RECRUITERS HISTORICAL PRODUCTION

Table 25 summarizes the data received from USAREC. Some of the original raw data had to be discarded because some production amounts were less than zero and some recruiter counts were also less than zero. This data was assumed to be either incorrectly coded or that this data came from new recruiting stations. Still, the data from at least 1,250 recruiting stations was used for each month, which should still give a good approximation of the average number of recruiters and accessions achieved.

The overall average of recruits achieved per recruiter was 6.85/4.95 = 1.38. The previous year's NHPL was about 1.29 recruits per month.

Month	Average Number of Recruiters per Recruiting Station	Average Number of Recruits Accessed per Recruiting Station
Oct 94	4.81	7.18
Nov 94	4.78	5.98
Dec 94	4.78	7.02
Jan 95	5.08	7.51
Feb 95	5.08	6.81
Mar 95	5.06	6.88
Apr 95	4.96	6.75
May 95	4.97	6.86
Jun 95	4.96	6.26
Jul 95	5.03	7.27
Average	4.95	6.85

Table 26 Historical Production Level (Oct 94- Jul 95)

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